TROPICAL AGRICULTURE

THE OFFICIAL JOURNAL OF THE
IMPERIAL COLLEGE OF TROPICAL AGRICULTURE

VOL. XVII. No. 4 APRIL, 1940. PRICE 6d.

CONTENTS.

	PAGE.
Food Production in the Wet Tropics ...	61
Aphid Vectors of Sugar Cane Mosaic ...	62
Some Economic Aspects of the Gall Midges (Diptera, Cecidomyidae) with Special Reference to the West Indies	63
Self-Incompatibility in Cocoa (Theobroma Spp.)	67
Observations on Behaviour of Citrus Root Stocks in St. Lucia, Dominica and Montserrat	72
Preparation of Citrus Fruit Juices ...	77
Reviews	79
Miscellaneous Notes	79
Chemical Notes	80

THE IMPERIAL COLLEGE OF TROPICAL AGRICULTURE, TRINIDAD, B.W.I.

Cables :: "Stomata." | Phone :: 2183

TROPICAL AGRICULTURE is published monthly at the Imperial College of Tropical Agriculture, St. Augustine, Trinidad, West Indies. Advertisement and subscription rates can be obtained at the College from the Editor, or from the Secretary of the College, Broadway Bldgs., Westminster, S.W. 1, England. The Editor will be glad to consider authoritative articles for publication. It is understood that opinions expressed or recommendations made in signed articles or in articles of which the source is named are those of the author and do not necessarily represent the policy or opinion of the College Authorities. Increasing numbers of inquiries are being received from the various parts of the tropics which can be answered only by persons possessed of an intimate knowledge of local conditions. Enquirers should first satisfy themselves that their local Department of Agriculture is not able to supply them with the desired information before communicating with us. Correspondence which will be replied to is invited on all other matters pertaining to tropical agriculture, science and development.

FOOD PRODUCTION IN THE WET TROPICS.

THE importance of ensuring an adequate food supply whether in time of war or peace cannot be over-estimated and it should therefore be profitable to consider the fundamental factors which govern the economic production of food. In this article we shall only concern ourselves with the question as it affects the wet tropics or those tropical parts of the Colonial Empire which lie near the sea, whose climate is characterised by a high humidity and a high rainfall distributed throughout the year. Such conditions contrast sharply with other regions in the tropics and other parts of the world where a semi-arid climate with long dry seasons obtains. In several colonies the coastal areas possess the typical wet tropical climate and the hinterland the tropical semi-arid climate; there must theoretically be border areas with intermediate climate but for our purposes such areas may be disregarded as being of comparatively small extent.

A fundamental difficulty in food production in the wet tropics appears to arise from the fact that these parts of the world are not particularly suited to the production of the annual arable food crops. On the other hand they are eminently well adapted to the production of such important staple crops as cacao, rubber, oil and coconut palms, coffee, tea, sugar cane, bananas and others. In fact these crops are strictly or almost strictly peculiar to the wet tropics. They can generally not be grown at all and can never be grown economically outside these areas. Moreover, the area in which they can be produced is limited since the wet tropics in total extent are relatively small as compared with the continental plains and plateaux of the semi-arid and temperate regions.

Another distinct disadvantage of the wet tropics for the production of food is that wage rates are generally relatively high. The disparity between wages and the price of food is typical of the economics of the wet tropics. For example, there is little difference between the prices of foodstuffs in Trinidad and their prices far in the interior of Nigeria or the Gold Coast, but wages in the West Indies are several times higher. Similarly wages in the humid littoral parts of West Africa are much higher than in the dry interior. Other similar examples could be quoted.

Turning to the semi-arid tropical regions we find that these are well adapted to the production of the great staple foods such as maize,

rice, sorghum and the pulses. These crops cover a much wider range of climatic conditions and they can generally be grown also in the wet tropics. They are, however, produced more cheaply in the semi-arid continental plains than in the wet tropics, primarily because in a dry climate fertility is not lost by leaching during the growing of a crop as it is by tropical rains, and is cheaply renewed by dry fallowing—a process which is worse than useless under continuous rainfall. Large scale mechanical cultivation to which these continental plains are peculiarly suited is another important factor. Finally, some of the continental areas are still liquidating "virgin fertility". Since staple food crops are eminently suitable for transport and trade, the price in any particular region tends towards the world price.

Thus, apart from war and threats of war, it appears fundamentally sound that the wet tropics should concentrate their attention mainly on producing the essentially tropical products, which they alone can produce, and import much of their staple grain foods from the semi-arid or temperate regions.

In spite of these objections to the large scale production of staple grain foods in the wet tropics there are some factors definitely favourable to the production even in peace time of food in these regions, particularly on a limited scale for local consumption. Apart from the main staples, local production of food should include the growth of root crops, green vegetables, fruits and, above all, animal products, for these cannot be shipped cheaply from overseas. Where such staple foods as maize or rice are concerned it will be obvious that the local producer is advantageously situated in his own local market, especially if he can sell directly or nearly directly to the local consumer, so as to eliminate all the middleman's costs and profits. Another factor favourable to local food production is the relative cheapness of the peasant labourer who is content with a small cash income and whose whole circumstance is well suited for mixed farming.

In view of the foregoing we may ask what is to be the proper peace time policy for a "grow more food" campaign in the wet tropics? From what has been said it is clear that the production of staple foods like maize should not be our primary object. Peasants can admittedly produce rice, but in view of the very low standard of living that is in general obtained by rice growers overseas, the home producer will only secure a moderate standard under very favourable conditions. Generally, the main object of the tropical food producer, at least in peace time, must be the ancillary food-stuffs, root crops and fruits, vegetables and animal products, rather than the staple grains and pulses. This does not mean that the staple products should not be grown at all by the food producer of the wet tropical countries. On the contrary, he will need to grow them for his own use and for the sake of diversifying and rotating his crops. But it does mean that the staple grains should not be regarded as the primary object of the tropical producer, to be grown at all seasons and in all conditions, favourable or unfavourable. The staple grain crops must be of secondary importance to the tropical farmer—crops to be grown only at the time of the year specially suited to them, to cover the gap between the other crops or to yield food or forage for his animals.

The keeping of stock and the sale of animal products must be the basis of peasant agriculture because this is a peculiarly suitable kind of occupation for the peasant. Its products are ones wherein local sale has a maximum economic advantage; and finally farmyard manure is the tropical arable farmer's weapon of defence for his soil against the tropical rains that so quickly steal its fertility.

Again, since we should take advantage of the suitability of peasant labour, the object of Government should not be to discourage the peasant from wage earning or from growing tropical staples, but only to ensure that he devotes some reasonable proportion of his holding to food production. This will be a reasonable policy, of which the peasant will appreciate the wisdom and sense. It is a policy that may therefore be effective. The alternative "whole hog" measure of trying to prevent the peasant from growing a staple crop at all in order to force him to put all his land to food production is unwise, will be resented, and will therefore not be effective.

Finally, every means should be taken to assist the peasant to sell the food products, which he produces in little more than retail quantities. It should be appreciated in this connection that the market stall where the producer sells direct to the consumer has a great economic advantage over any elaborate system of marketing whether by middlemen or even by co-operative organisations.

In this article we have only discussed food production in peace time. In war time Colonial Governments may well have to modify their policies very greatly and disregard the fundamental factors of peace time economy by introducing such restrictive and other measures as they may think fit.

APHID VECTORS OF SUGAR CANE MOSAIC.

The aphid *Aphis maidis* has been recognized for a considerable time as a transmitting agent for the sugar cane mosaic virus. H. D. Tate and S. R. Vandenberg have shown, however (*J. Agric. Res.*, 59, No. 1, 73-80, 1939), that two other aphis, *Carolinaia cyperi* and *Hysteroneura setariae*, which may occur on the crop in Puerto Rico, are also vectors of this particular disease. These insects inhabit the weeds *Cyperus rotundifolia* and *Eleusine indica* (goosegrass), which are common in sugar cane plantations, and doubtless play a considerable part in the spread of mosaic under field conditions. A fourth kind of aphid, *Sipha flava*, was unable to transmit the virus. The results supply yet another instance of the close relation between a virus and its insect vector.—(*Nature*, Vol. 144, No. 3658, p. 984.)

SOME ECONOMIC ASPECTS OF THE GALL MIDGES (DIPTERA, CECIDOMYIDAE) WITH SPECIAL REFERENCE TO THE WEST INDIES.

By E. McC. Callan, B.Sc., Ph.D.
(*Entomology Department, Imperial College of Tropical Agriculture, Trinidad, B.W.I.*)

Introduction.

The Cecidomyidae or gall midges comprise a large number of delicate and minute flies. They are most easily recognised by their long antennae, which bear conspicuous whorls of setae, and by the reduced wing venation consisting of a few longitudinal veins with no obvious cross-veins. The larvae have a reduced head and range in colour from white through yellow and orange to red. Their most characteristic structure, which is absent in some species, is the anchor process or sternal spatula, situated mid-ventrally on the first thoracic segment. Various functions have been ascribed to this organ. Many larvae possess the power of leaping, the body being curved in the form of a loop and then suddenly released, by which a distance of several centimetres may be traversed. A valuable account of the biological and economic aspects of these insects is given by Barnes (2).

Larval Feeding Habits.

The larvae of the Cecidomyidae exhibit great diversity in their feeding habits, and may be classified into zoophagous and phytophagous species. The zoophagous gall midges include those in which the larvae are internal parasites and those in which they are predaceous. Very few species are known to be true parasites.

The predaceous gall midges comprise rather more than 130 species according to Barnes (2), and include those in which the larvae prey on other gall midge larvae, on mites and red spiders, on aphids, on scale-insects and mealy-bugs, on white-flies and on thrips. Thrips have very few natural enemies, but at least two species of gall midges are known whose larvae prey on these insects. One of these is *Thripsobremia liothripis* Barnes, which is predaceous on the thrips, *Liothrips urichi* Karny, in Trinidad (1). The zoophagous species are beneficial in so far as they attack and effect a potential natural control of insects and mites which are pests of crops.

The phytophagous gall midges comprise the majority of species of Cecidomyidae. They include those with larvae which live on or within plants without causing galls, which cause galls and which live as inquilines within galls caused by other insects. Many of the species whose larvae do not cause galls, live in the flowers of grasses feeding on the developing seed. Others live in flower-buds and in fruit, beneath the bark of shoots and in decaying vegetable matter. A large group feed on rusts and other fungi and may be regarded as beneficial.

The great majority of gall midges are true gall-causing forms, and, although all parts of the plant may be affected, the buds, leaves and stems seem to be most subject to gall formation. The Gramineae, Compositae and Salicaceae are most frequently attacked by gall-causing species. Comparatively few species live as inquilines within galls caused by other insects, but most of these are to be found in the galls of other Cecidomyidae.

Economic Importance.

Although the gall midges include few major pests, they are nevertheless of considerable interest to the economic entomologist, because of the wide variety of crops which suffer from their attacks. The most notorious species is undoubtedly the hessian fly, *Mayetiola destructor* Say, which is much the most important pest of wheat in North America. This species is of wide distribution and has received most attention in the United States of America, to which country it was introduced from Europe. Gall midges regarded as important pests include those attacking wheat, sorghum, pears, peas, tomatoes, cauliflowers, chrysanthemums, red clover, basket willows, hops and many other crops.

Although little information is available on the bionomics of the zoophagous species, many are known to prey on insects and mites. These gall midges, together with those which feed on rusts and other fungi, are to be regarded as beneficial and of some economic importance. Beneficial also are those phytophagous species which effect a natural control of injurious weeds, usually by the destruction of the seed.

Control Methods.

Gall midges are among the most difficult of all insects to control. Preventive control methods, such as protective legislation and plant quarantine measures, aimed at preventing the introduction and establishment of pests into new areas, are highly desirable. In this connection it is of interest to note that at least one species of gall midge (*Contarinia sorghicola* Coq.), which is a pest in the West Indies, is almost certainly a recent introduction into this area.

Gall midges are subject to attack by various natural enemies, the most important being Chalcidoid and Proctotrupoid parasites, of which more than 40 species are recorded from the hessian fly alone. These parasites undoubtedly often effect an important natural control. No serious attempt, however, has so far been made in the use of parasites against these pests, and their biological control remains for the future.

The presence of the larvae within galls, and in such situations as within the developing seeds of grasses, in flower-buds and in fruit and beneath the bark of shoots, renders gall midges particularly unsuitable for chemical control by the application of insecticides. Attempts have been made, however, to control those species whose larvae enter the soil for pupation by the application of a dressing of such insecticides as naphthalene and paradichlorbenzene to the surface layers of the soil. The chrysanthemum midge is one of the very few species which have been effectively controlled by the use of insecticides. Derris, pyrethrum and nicotine sprays have been used successfully against the eggs and adults of this pest. Pyrethrum and nicotine dusts and fumigation with both hydrocyanic acid gas and nicotine in the vapour phase have also proved effective in killing the adults.

Cultural methods of control are by far the most important measures used against gall midge attacks. They are based on a knowledge of the ecology of the insect in relation to its host plant, and aim at modifying cultural practice, so that the pest is placed at a disadvantage. The regulation of the growth of the crop is one such method in general use. This may take the form of an alteration of the time of planting, or the promotion of rapid growth of the crop, so that it becomes less liable to infestation. The time of sowing is of great importance as regards the attack of the hessian fly and the sorghum midge. The crop should be planted at such a date that it will flower either early or late, so as to avoid the main gall midge attack. In practice the sowing of the crop is usually delayed until a date which ensures that flowering will occur after the main emergence of gall midges has ceased. The encouragement of rapid growth may be brought about by manurial treatment and intensive cultivation, and the crop thereby rendered less susceptible to infestation.

Measures of general crop hygiene are among the most useful of cultural methods. The destruction of outside sources of infestation such as alternate host plants and volunteer or self-sown plants is advocated. Other practices include a thorough clean up and the destruction of all plants immediately after the crop is harvested, together with a close season when no plants are available for the maintenance of a gall midge population. The rotation of crops is also recommended wherever practicable, as the pest is thereby placed at a serious disadvantage.

Some work has already been done on the varietal resistance of plants to gall midge attack, especially as regards the hessian fly and the willow midges. So-called resistance often implies no more than a low degree of susceptibility to attack, the underlying causes conferring this resistance usually involving a number of contributing chemical, physical and biological factors. The discovery and exploitation of plants, which have a high varietal resistance to gall midge attack and at the same time desirable agronomic characters, will assuredly be one of the main lines of assault against these pests in the future.

West Indian Gall Midges.

The geographical distribution of the Cecidomyidae is world-wide, but, while the European and North American faunas have been intensively studied, those of other parts of the world are little known. According to Barnes (2) about 3,500 species have been described. Comparatively few gall midges, however, have been recorded from the neotropical region. A critical survey of the literature shows that less than 50 species have been described from the West Indies (4), and it seems certain that at least as many more await discovery.

By far the largest number of species have been recorded from St. Vincent. This is not because St. Vincent has a richer gall midge fauna than the other islands, but due almost entirely to the work of Patterson (5, 6), who was not only an extensive collector but also an extremely careful observer and records 20 species from that island.

I am unaware of any authentic records of described gall midges from Cuba, Haiti or Santo Domingo; Martinique or Guadeloupe, F.W.I.; Grenada, Dominica or Tobago, B.W.I. That such records exist and have not yet been brought to light seems especially likely with regard to Cuba. There can be little doubt that numerous species of gall midges occur in all these islands.

The insect fauna of the West Indies is derived from two main sources: a northern South American fauna continental in character and an Antillean fauna. The Antillean fauna may be further subdivided into Greater and Lesser Antillean components. The continental fauna is especially well seen in Trinidad and, although less extensive, in the neighbouring island of Tobago, but only influences the more southerly of the Lesser Antilles and diminishes rapidly northwards. The Greater Antillean fauna exerts an influence only upon the more northerly of the Lesser Antilles. The Lesser Antillean fauna is at times oceanic in character and includes a number of endemic species. Overlying the whole is an incursive fauna of recent introductions.

The West Indian gall midges are derived from all these sources, and include some sixteen described species which are of potential or actual economic importance. Only eight of these species are phytophagous and can be considered as pests, while the remaining eight are zoophagous in habit and may be said to be beneficial in that they prey upon scale-insects. The present paper deals only with those species which are known definitely to be injurious to crops.

Species of Economic Importance.

The following gall midges can be considered as pests of the crops indicated in the West Indies :—

1. *Contarinia gossypii* Felt (cotton).
2. *C. lycopersici* Felt (tomatoes).
3. *C. sorghicola* Coq. (sorghum).
4. *Porricondyla gossypii* Coq. (cotton).
5. *Iatrophobia brasiliensis* Rübs. (cassava).
6. *Asynapta citrinae* Felt (citrus).
7. *A. mangiferae* Felt (mangoes).
8. *Erosomyia mangiferae* Felt (mangoes).

In a subsequent paper (3) these pests are dealt with at some length, accounts being given of their life-histories, as far as these are known, and the nature and extent of the damage caused to crops. The present economic status of the pests is considered and suggestions made as to the most practical methods of control.

Contarinia gossypii Felt is apparently an endemic Lesser Antillean species. The larva is known as the flower-bud maggot of cotton, and first appeared in Antigua in 1907, causing serious damage to cotton for two successive seasons. The larvae infest and cause marked injury to the flower-buds, resulting almost invariably in a characteristic flaring of the bracts in the young buds, which is followed by shedding. The older buds do not usually flare their bracts and are not shed, but are rendered incapable of producing bolls. This pest has been reported in subsequent years, but in comparatively few seasons has considerable damage resulted. It has also been reported in Montserrat, in Tortola in the British Virgin Islands, in St. Croix in the American Virgin Islands and more recently in Florida, U.S.A. There have now been no reports of severe damage for a number of years and, although once of considerable economic importance, at the present time it can only be regarded as a minor pest of cotton.

Contarinia lycopersici Felt is an extremely interesting species, which appears to be endemic to the Lesser Antilles. It can appropriately be called the tomato flower midge, and is undoubtedly one of the most important Cecidomyid pests in the West Indies. This species does not appear to be generally distributed, but, where it occurs, is to be regarded as a major pest of tomatoes. The larvae infest and cause considerable injury to tomato flowers, as a result of which they either wither and are then often shed or the ovary is damaged, resulting in a malformation of the fruit. It has been reported as damaging tomatoes in St. Vincent, Trinidad, Barbados and probably Hawaii. I have found this species in Trinidad and in tomato flower-buds sent to me from Grenada. I have not found it, however, in Tobago nor in samples of tomato flower-buds from Haiti, St. Lucia, Dominica and Montserrat, but this does not mean that this pest is necessarily absent from these islands.

The record from Hawaii requires some explanation and is discussed more fully elsewhere (3, 4). Briefly, Dr. H. F. Barnes is of the opinion that a species, reported as damaging tomatoes in Hawaii, was erroneously determined as *C. solani* Rübs., a European form, and is in fact *C. lycopersici*. In this case it is the only record, as far as I am aware, of the introduction into another region from the Caribbean area of this apparently autochthonous West Indian species.

Contarinia sorghicola Coq. is the sorghum midge and is apparently a recent introduction into the West Indies. It is well known in the United States of America, where it is the most important pest of sorghum (*Sorghum vulgare* L.). The larvae live within the developing seeds causing them to shrivel and resulting in a characteristic blasting of the spikelets of the sorghum head. Infestation is often very high and a complete loss of the crop may result from a severe attack. Besides the United States, this pest has been reported attacking sorghum in Hawaii and more recently in the Sudan. In the West Indies it has been reported in Curaçao, D.W.I., St. Vincent and the American Virgin Islands. I have found it commonly in Trinidad attacking Guinea corn, broom corn, Sudan grass and Johnson grass (*Sorghum halepense* Pers.), the latter being an alternate wild host. Although sorghum is not extensively grown in the West Indies, except in the drier islands such as Curaçao, the sorghum midge is undoubtedly to be regarded as its most important pest in this region and often causes a serious loss of the crop.

Porricondyla gossypii Felt is apparently an endemic Lesser Antillean species. The larva has been called the red maggot of cotton, and first appeared in Barbados in 1903. This is the only island where it has been recorded as a pest, although it is also known to occur in Montserrat. The larvae occur in numbers beneath the bark of the stem and feed in the cambium, severe attack resulting in the stem being girdled. Although on occasion this pest has caused serious injury to cotton in Barbados, there have been no reports of severe damage for many years, and at the present time it can only be regarded as a minor pest of this crop and is chiefly of historical interest.

Iatrophobia brasiliensis Rübs., is a South American species almost certainly indigenous to Brazil, reaching its northern limit of distribution in the Lesser Antilles. I am aware of no records of its occurrence further north than St. Vincent, but it is not unlikely that it occurs in a few of the more northerly islands. It is a gall-causing species, recorded in the literature from Brazil, Trinidad and St. Vincent, causing conspicuous reddish galls on the leaves of cassava (*Manihot utilissima* Pohl). I have found this species in British Guiana, Trinidad and Tobago ; in Trinidad it is ubiquitous and galls are sometimes extremely numerous, but it appears to be very much rarer in Tobago. Usually these galls are not sufficiently numerous to affect the development of the plant adversely, although on occasion they may be extremely abundant, the leaves then being completely deformed and the growth of the plant retarded. This gall midge, in Trinidad at any

rate, can only be regarded as a relatively unimportant pest, severe injury to cassava rarely resulting from its attack.

Asynapta citrinae Felt is only known from Puerto Rico, where it has been reported as a pest of citrus. The larvae live beneath the bark of grapefruit shoots mining in the cambium. The economic status of this pest is uncertain, but it is probably only of minor importance.

Asynapta mangiferae Felt is only known from Barbados, where it has been reported as a pest of mangoes. The larvae live under the bark of small shoots of grafted mango (*Mangifera indica* L.), feeding probably in the cambium and causing the death of the terminal parts of the shoots. The pest appears to be of minor importance.

Erosomyia mangiferae Felt appears to be endemic to the Lesser Antilles, and is recorded from St. Vincent and also from plants imported from St. Lucia. According to Patterson (6) the larvae infest and frequently destroy the inflorescences and also cause galls on the young newly expanded leaves of mango (*Mangifera indica* L.) in St. Vincent. A gall midge attacking mango inflorescences in Trinidad has been reported by Urich (7), who gives an account of its life-history, describes the nature and extent of the damage caused and makes suggestions for control. As far as I am aware this species has never been described, but, so precisely does the account of the nature of the damage as given by Urich agree with that of Patterson, that I feel reasonably certain that the Trinidad and St. Vincent insects are the same species. This can only be conclusively demonstrated when Trinidad specimens have been compared with Felt's type of *E. mangiferae* and with his original description of the genus and species.

Cacao Flower Midges.

A number of additional gall midges from Trinidad have not yet been studied in detail. These include species associated with cacao and attacking the flowers and young shoots of mangoes. Others have been reared from larvae associated with the mace of nutmegs and from galls on camphor, mangrove and other leaves.

The species associated with cacao have been found on many occasions in the flowers and in large numbers on the undersides of the leaves and resting festooned on spider-web. The chief interest which attaches to these cacao flower midges, of which there appear to be two distinct species, is that they may prove to be one of the agents effecting cross-pollination in cacao. A number of insects have been suspected as pollinating agents in cacao, and, should these midges prove to be such, they would be of considerable economic importance.

It is also of interest to note that one of these gall midges apparently occasionally lays its eggs in cacao flowers. The eggs have not been observed, but larvae have been found on occasion in the flowers, as many as fourteen larvae being obtained from a single flower. It is not yet certain whether it is the normal habit for the larvae to live in cacao flowers. The larvae of many gall midges, however, are known to attack flowers, and the vast majority of Cecidomyidae show marked host specificity, being restricted to a single plant species. One species of cacao flower midge must therefore be considered as a potential pest of cacao. It would be highly ironical should this species be shown also to be an agent of pollination.

Summary.

1. The larval feeding habits and economic importance of the Cecidomyidae are discussed.

2. Control measures are reviewed, cultural methods being considered of most importance.

3. The West Indian gall midge fauna is discussed with reference to the sources from which it has been derived.

4. The following eight species are considered as pests of the crops indicated in the West Indies: *Contarinia gossypii* Felt (cotton), *C. lycopersici* Felt (tomatoes), *C. sorghicola* Coq. (sorghum), *Porricondyla gossypii* Coq. (cotton), *Iatrophobia brasiliensis* Rübs. (cassava), *Asynapta citrinae* Felt (citrus), *A. mangiferae* Felt (mangoes) and *Erosomyia mangiferae* Felt (mangoes).

5. Each species is dealt with as regards derivation and geographical distribution. The nature of the damage caused is briefly outlined, and the present economic status of each pest considered.

6. *Contarinia lycopersici* and *C. sorghicola* are regarded as the two most important Cecidomyid pests in the West Indies, being major pests of tomatoes and sorghum respectively.

7. Cecidomyid larvae and two apparently distinct species of gall midges are reported from cacao flowers. It is suggested that these cacao flower midges may prove to be one of the agents effecting cross-pollination in cacao.

Acknowledgments.

I wish to express my indebtedness to Dr. H. F. Barnes of the Rothamsted Experimental Station, England for advice and for the determination of *Contarinia lycopersici* Felt, *C. sorghicola* Coq. and *Iatrophobia brasiliensis* Rübs.

References.

(1) Barnes, H. F. (1930.)—A new thrips-eating gall midge, *Thripsobremia liothripis*, gen. et. sp. n. (Cecidomyidae). *Bull. Ent. Res.*, **21**: 331-332.

(2) Barnes, H. F. (1934).—Some biological and economic aspects of the gall midges. *Science Progress*, London, **29**: 73-86.

(3) Callan, E. McC. (1940).—The gall midges (Diptera, Cecidomyidae) of economic importance in the West Indies. *Tropical Agriculture*, Trinidad, **17** (in preparation).

(4) Callan, E. McC. (1940).—The gall midges (Diptera, Cecidomyidae) of the West Indies. *Rev. Ent.*, Rio de Janeiro, **11** (in the press).

(5) Patterson, W. H. (1911).—Report on the Agricultural School, St. Vincent, 1909-10, 19-20. *West Indian Agric. Reports.*

(6) Patterson, W. H. (1912).—Report on the Agricultural School, St. Vincent, 1910-11, 20-23. *West Indian Agric. Reports.*

(7) Urich, F. W. (1921).—The mango midge. *Bull. Dept. Agric.*, Trinidad and Tobago, **19**: 110.

SELF-INCOMPATIBILITY IN COCOA (THEOBROMA Spp.).

By A. F. Posnette.
(*Botanist, Department of Agriculture, Gold Coast.*)

[*This paper which was submitted to the Third West African Agricultural Conference held in Nigeria in* 1938 *is published by courtesy of the Acting Director of Agriculture, Gold Coast. The paper represents another contribution to the study of incompatibility in cocoa. In order to avoid misunderstanding as regards more recent references it should be noted that it was prepared in March,* 1938.—Ed.]

Introduction.

For many years speculation has been rife as to the causes of the disparity between cocoa yields in West Africa and the West Indies. C. Y. Shephard (1) reporting on Gold Coast Agriculture, maintains that the difference in age is the primary factor, writing that yields in Trinidad were slightly larger, and in Grenada very much higher, at comparable ages, than any claimed for the Gold Coast. He forecasts diminishing production per acre unless extensive planting is resumed.

Voelcker (2) with botanical experience in both countries, doubts that West Indian figures ever reached the 900 lb. per acre known to occur both in Nigeria and Gold Coast, and suggests that the prevalence of self-incompatibility recently proved on Trinidad estates may be restricting yield, owing to inefficiency of the cross pollinating mechanism.

The present writer carried out experiments in Trinidad (3) on self-incompatibility and pollination, finding that the restriction of insects does depress yield markedly, even on self-compatible trees, though the actual insect concerned has not been detected conclusively as yet.

The investigations to be described in this paper were carried out at Aburi to discover if the self-incompatible type is present on the Gold Coast, and to what extent this factor may influence yield. The initial results disclosed further possibilities of elucidating the nature of the sterility.

It is perhaps advisable to give a brief account of what was known of the nature of self-incompatibility, a factor well known in temperate fruit crops, rubber and tea. It was first noticed in cocoa by Pound (4) in 1931 who considered that it was only a temporary state into which trees entered for a varying period. If flowers stayed on the tree for six days after hand pollination he considered them "set"; during part of the year he found selfed flowers staying on over six days on what he had previously considered self-sterile trees (most unpollinated flowers fall off the day after opening; all flowers two days after).

Voelcker and the present writer found in Trinidad that if a longer period is taken (ten or fourteen days) as the criterion of setting, no flowers are set on self-incompatible trees, although the ovary may show all external signs of fertilisation for several days. On such trees only by cross-pollination can setting be effected.

Two types of trees are recognised; the self-compatible tree will set fruit with its own or any other pollen; the self-incompatible tree can pollinate a self-compatible tree but itself will only set when pollinated with a self-compatible type. The incompatible type can be recognised in the field with some accuracy by its continuous flowering habit with dense clusters of flowers on raised cushions.

Incompatibility and Yield.

The self-incompatible type appears to be very prevalent on Trinidad estates. The majority of the I.C.S. selections tested have proved to be self-sterile, so that provided the tree has suitable pollinators as neighbours, this factor is no bar to high yield. The chief significance arises when one considers laying out an experiment in which clonal plots are to be used. Clonal material is the only satisfactory medium for experimentation, and it is indispensable for a progeny trial with a perennial crop. It would appear that a clonal block of self-sterile trees would not do itself justice in the absence of suitable pollinators and cross-pollinating agents. The findings at Aburi support this view.

The Aburi cocoa proved exceptionally convenient for a study of the various aspects of incompatibility not only because this factor was found to be extensively distributed, but because yields have been recorded since 1914. It is the writer's contention that self-incompatibility is one character of the type formed by cross-pollination between Criollo and Forastero types. The Trinitario complex (a convenient term covering the various types intermediate between pure Criollo and pure Amelonado) as grown in Trinidad and other "quality" producing-countries, is a heterogeneous mixture formed by the gradual supplanting of the first quality Criollo by the hardier Forastero, with extensive interbreeding. One of the intermediate types is called Cundeamor, which is seldom a true-breeding variety. Many of the Trinidad I.C.S. selections are of this type, combining the plump bean and light break of the Criollo with the high yield and disease resistance of the Forastero. Voelcker has shown that many of these trees are self-incompatible.

The Cundeamor plot at Aburi, consisting of 86 trees, all but ten of which are self-incompatible, yields an average of 167 lb. of cocoa per acre. The trees are large and healthy, comparing favourably with the adjoining Amelonado plot in everything but yield. This plot has only six self-incompatible

trees out of 315, and yields at the rate of 889 lb. per acre. From October to April the Cundeamor trees were flowering profusely and continuously (a characteristic of the self-sterile type) yet setting was negligible. This seems to be a standing warning against planting pure plots of self-incompatible cocoa.

The self-sterile trees on the Amelonado plot have been shown by hand pollination to be surrounded by suitable pollinators, yet setting is comparatively low on them despite continuous flowering. The individual tree records show a convincing difference in yield.

Table I.

Tree No.	Type.	Average No. of Pods. 1914-37.
17	Incompatible	30.2
33	Incompatible	65.0
35	Incompatible	32.9
Ten neighbouring trees	Compatible	91.8

The four other self-sterile trees are younger so cannot be compared with the ten used in Table I. They tend to be Cundeamor type, presumably being supplies from Amelonado trees cross-pollinated from the Cundeamor plot.

Table II.

Tree No.	Type.	Average No. of Pods. 1927-37.
354	Incompatible	14.8
358	Incompatible	26.0
*372	Incompatible	66.3 *
387	Incompatible	5.3
Average of five neighbouring trees	Compatible	52.2

* No. 372 is at least twice the size of other trees of comparable age, so its yield cannot be compared fairly, being due chiefly to a favourable position.

These figures support the view that self-incompatibility restricts yield even though suitable pollinators are near, indicating that setting may be limited by lack of cross-pollinating agents. The tree No. 33 (Table I) illustrates this, since it consists of the original old trunk, self-sterile, and a young self-compatible chupon. This younger trunk, which bears far more than the old wood, undoubtedly accounts for the average of 65 pods per year being higher than that of the other self-incompatible trees of the same age.

The Criollo plot at Aburi consists partly of Criollo trees, but many are close to the Cundeamor and a few are typical Amelonado in shape, though they may be red or partly pigmented. It would appear that the seed came from Criollo trees partly cross-pollinated with some Forastero type.

Self-sterile trees predominate, there being two to each self-compatible tree. The average yield per acre (over the same ten years as that calculated for the other plots) is 352 lb. intermediate between the Cundeamor and the Amelonado. The order of yield of the three plots is thus inverse to the extent of self-incompatibility, though one would expect the Cundeamor, with some Forastero genes in its make-up, to yield more highly than the Criollo. That the difference in yield is not entirely varietal is also indicated by the low yield of the Amelonado incompatible trees. If the self-sterility is a contributing factor to low yield, being inherited, and absent from some trees of all varieties, it can be eliminated in future plantings far more easily than such yield factors as susceptibility to pod rot and canker which appear to be closely linked with the quality types.

In the light of this, the comparative values of the varieties need revision. If the yield of Criollo or Cundeamor is to be compared with that of Amelonado, self-compatible types must be chosen throughout. By selection from self-compatible trees it is possible that a strain of higher quality cocoa could be established not inferior in yield to the Amelonado. It certainly appears that the self-compatible Criollo trees are contributing the greater proportion of crop; future individual tree yields, which it is hoped will be taken in future on all three plots, may confirm this.

The Amelonado plot is typical of the cocoa grown commercially in West Africa. From general observations it appears that self-incompatibility is at present of rare occurrence on native farms, and from the foregoing evidence, this may be an important reason for yields being so much higher than in the West Indies.

Causes of Self-incompatibility.

Incompatibility and age of tree.—The presence of the young self-compatible water-shoot on the old self-sterile tree (No. 33) might indicate that incompatibility is a sign of old age. Many of the original Amelonado trees have been rejuvenated

Table III.

Tree No.	Young Trunk.			Old Trunk.		
	No. flowers polli-nated.	No. set.	Type.	No. flowers polli-nated.	No. set.	Type.
33	7	7	C	22	O	In
244	18	9	C	14	O	In
14 other trees of same age	52	43	C	63	46	C

similarly by allowing a chupon to develop into a second trunk; these were hand-pollinated to investigate this possibility. One further example (No. 244)* was found, but otherwise young and old wood were of the same type (Table III). Of the self-sterile trees on the Amelonado plot, four are young (bearing commenced 1926-7) and three are old (bearing since 1914).

It appears that these two changes in compatibility are due to bud mutations.

Pollen-tube growth.—Previous writers have distinguished between two types of tree only—the self-incompatible always setting with pollen from a self-compatible tree. At Aburi instances have been found in which a self-sterile tree is fertile only with certain self-compatible trees, and not compatible with others. This favours the genetical interpretation applicable to temperate fruit crops. The pollen tubes are inhibited if they carry the same gene as the style in which they are growing. The self-pollinations are then ineffective because the pollen tube grows too slowly down the style and the flower falls before fertilisation.

Histology.—Previous microscopical work by the writer (3) showed that incompatible pollen germinates as well on the style as compatible, and that there is some indication of slower growth and perhaps of complete inhibition of the pollen tube at the base of the style. In continuing this work at Aburi, the chief difficulty remained that of obtaining for pollen tubes an efficient stain which will penetrate the mucilaginous stylar tissues. Until this has been found, it is impossible to be certain of the progress of the pollen tubes growing down the stylar canal. In microtome sections using Haematoxyline, Methylene blue and Safranine no differential staining has occurred, but there is no apparent difference between sections of pistils after compatible or incompatible pollination.

Pollen growth in Agar.—Pollen growth in Agar 5 per cent. sucrose is satisfactory but both compatible and incompatible pollen tubes show a slight tendency to grow towards ovules and stylar tissue embedded in the Agar.

Double pollinations.—To test the relative speeds at which the pollen tubes grow down the style, compatible and incompatible pollinations were done on the same flower—

(*a*) at the same time (Table VI),
(*b*) at various intervals of time (Tables VII and VIII),
(*c*) at different regions of the pistil (Tables IX and X).

Flowers were considered set if the cherelles appeared healthy 10 days after pollination. Interpretation of the results is made more difficult by the fact that all self-sterile trees do not behave alike when crossed with a self-compatible type. Thus tree No. 22 was incompatible with pollen from Nos. 10 and 12, but compatible with Nos. 18 and 62. The pollen of 10 and 12 was compatible with all other self-sterile trees tried. Control self- and cross-pollinations are given in Tables IV and V.

Table IV.

CONTROL: SELF-POLLINATIONS.

Tree.	No. Pollinated.	No. Set.	Type.
Cr. 10	23	12	C
Cr 12	12	10	C
Cr 13	20	0	In
Cr 14	56	0	In
Cr 18	5	4	C
Cr 22	10	0	In
Cr 24	11	0	In
Cr 37	12	0	In
Cr 38	20	0	In
Cr 54	10	0	In
Cr 62	4	4	C
Cr 67	14	1	In
A 214	10	6	C
A 354	27	0	In
A 358	22	0	In
A 372	39	0	In

Table V.

CONTROLS: CROSS-POLLINATIONS.

Female.	Male.	No. Pollinated.	No. Set.
13	10	10	9
13	12	6	5
13	22	10	0
14	10	8	6
14	12	4	3
22	18	12	7
22	62	4	4
24	18	5	5
37	12	6	5
38	12	6	5
38	62	5	5
54	62	4	3
67	62	7	5
354	214	4	4
358	214	5	4
372	214	8	6
Total	...	104	76 73.4%

TIME RELATIONSHIPS.

(*a*) *Double pollinations at the same time.*—The results in Table VI show the different behaviours of self-sterile trees when self- and cross-(compatible) pollen is applied to the stigma simultaneously. The figure of 24.4 per cent. setting does not give a very adequate picture as with some trees (*e.g.* No. 22) no sets are obtained, with others (*e.g.* No. 13), about half the pollinations set. With No. 14 the result depends on the pollen parent.

* Since this paper was prepared, another large incompatible tree with self-compatible chupons has been found on a native farm.

(*b*) *Double pollinations at different times.*—Table VII shows results when selfing precedes crossing by two hours. Only 38 × 12 shows appreciable setting, whereas 38 × 10 gives no sets.

By contrast, Table VIII shows considerable setting on most trees when crossing precedes selfing by two hours, though not to the same extent as when self-pollen is absent.

Table VI.

SELF AND CROSS POLLEN ON STIGMA (AT SAME TIME).

Female.	Male.	No. Pollinated.	No. Set.
13	10	8	4
13	12	9	7
14	10	12	0
14	12	12	5
22	62	12	0
22	18	8	0
24	18	12	4
37	12	12	6
38	10	12	2
38	12	8	6
54	62	10	2
67	62	10	2
354	214	20	2
358	214	10	1
372	214	10	0
Total	...	165	41 24.4%

Table VII.

CROSS TWO HOURS AFTER SELF (BOTH ON STIGMA).

Female.	Male.	No. Pollinated.	No. Set.
13	10	10	2
13	12	10	2
14	10	20	5
14	12	10	0
22	62	10	0
38	10	10	0
38	12	10	7
Total	...	80	16 20%

Same crosses six hours after selfing gave no sets.

Table VIII.

SELF AFTER CROSS.

Female.	Male.	No. Pollinated.	No. Set.
13	10	10	4
13	12	10	4
14	10	10	5
14	12	10	1
22	62	10	3
38	10	10	5
354	214	20	12
358	214	20	13
372	214	20	15
Total	...	120	62 51.6%

SPACE RELATIONSHIPS.

(*c*) *Double pollinations at different regions of the pistil.*—The pistil of the cocoa flower has a style from 1.5 to 2 mms. long terminating in a five-lobed stigma about .8 mm. long. This allows pollen to be applied with sufficient accuracy either on the stigma, or on the base of the style. The distribution is probably not always completely correct—some grains may fall on the style when the stigma is brushed and *vice versa*. Controls showed compatible pollen to be equally potent, incompatible pollen equally ineffective, whether applied to the stigma or to the base of the style; but in the presence of incompatible pollen, compatible pollen causes setting only when applied to the style, thus having a shorter path to the ovary. A comparison of Tables IX and X shows this clearly.

Table IX.

SELFED ON STIGMA : CROSSED ON STYLE (AT SAME TIME).

Female.	Male.	No. Pollinated.	No. Set.
13	12	8	4
14	10	10	9
14	12	10	7
22	62	10	3
24	18	10	9
354	214	8	6
358	214	10	4
372	214	10	8
Total ...	...	76	50 65.8%

Table X.

SELFED ON STYLE : CROSSED ON STIGMA (AT SAME TIME).

Female.	Male.	No. Pollinated.	No. Set.
13	12	5	0
14	10	8	0
14	12	9	0
22	62	6	0
24	18	8	0
354	214	10	1
358	214	10	0
372	214	10	1
Total ...	...	66	2 3%

Discussion.

Self-incompatibility is a general feature of tropical crops, having been investigated in citrus, rubber, tea, coffee and tobacco. These fall in line with temperate orchard crops, the cause in which is the slow growth of the incompatible pollen due, on the oppositional factor theory, to the inhibition of pollen tubes having the same genetical factor as the style in which they are growing. The flower thus abscisses before

fertilisation, though by giving incompatible pollen a shorter distance to grow (amputating the style) or a longer time (pollinating in the bud) setting can sometimes be effected. In cacao, neither of these methods is productive.

The early stages of setting involve an inhibition of the abscission mechanism of the flower by the stimulus of pollination which may be unaccompanied by fertilisation, as in citrus. Even incompatible pollen results in some delay of abscission of the cocoa flower, accompanied by swelling of the ovary. As has been mentioned already, ten days is required as a criterion of setting whereas unpollinated flowers fall after two days. This initial development of the ovary is regarded as the result of pollen stimulation only.

Cheesman (5) has shown that fertilisation normally occurs within six hours after pollination, the tubes reaching the micropyles in four hours. Allowing for a lag in germination, a start of two hours should mean that the pollen first applied has grown about half-way down the style when the second application is made. The results of this experiment do not necessarily indicate that the growth of incompatible pollen tubes is much, if any slower than that of compatible pollen, for if it were, the simultaneous double pollinations, and crossing two hours after selfing would have given a greater proportion of sets. In some cases, incompatible pollen applied two hours after compatible reduced setting. In the cross 22 × 62 particularly, and to a lesser extent in others, the presence of incompatible (self) pollen in any relation to the cross-pollen reduced settings.

Two possible interpretations come to mind. The incompatible pollen tubes may grow far more rapidly than the compatible, and usually effect fertilisation, after which lethal factors operate to counteract the inhibition (which normally occurs on pollination) of the flower abscission mechanism and which is initiated even by incompatible pollen. The initial abortive growth of ovaries after sterile pollinations support this theory, but the setting obtained from double pollinations seems to indicate that pollen tube growth of the two types is about equal.

A second explanation of the effect of incompatible pollen on compatible when growing in the same style does not necessitate the former reaching the ovary—and there is some slight histological evidence that it does not. Under the influence of incompatible pollen, the style may produce a pollen tube inhibitor. Sears (6) has likened the response of cruciferous stylar tissue with incompatible pollen to that of the reaction of immune tissue against fungal penetration. The production of antibodies may be part of this, and the pollen tube inhibitor thus evoked by incompatible pollen, may also cause a block to compatible pollen tubes. The latter can reach the ovules only if given a start so as to grow beyond the stigma by the time the inhibitor is produced, or if placed on the style while the incompatible pollen is inducing the inhibitor in the stigmatic region. This theory fits in with the experimental results obtained to date.

Further proof can be obtained in two directions. A histological preparation showing incompatible pollen effecting fertilisation will support the first theory. It may be possible to prove that some incompatible pollen effects fertilisation together with some compatible, when they are applied together, by the genetical study of a self-incompatible white-beaned type crossed with a purple-beaned pollen parent. Since the light bean is a recessive character it will show only on self-pollination (or crossing with another light bean type), so the presence of light beans in a pod the result of a double pollination will indicate that both types are reaching the ovary.

Until this is done the theory of an inhibitor seems to fit the facts satisfactorily; different pollen is variously affected by the inhibitor, thus explaining the results which vary with the pollen parent used. Incompatible pollen tubes are completely inhibited before reaching the ovary, while varying degrees of sterility are to be expected according to the susceptibility of the pollen tubes to the inhibitor.

Summary.

1. The cocoa on Aburi Experiment Station has been tested for self-incompatibility, which is found to be least common in the Amelonado and most common in the Cundeamor, with Criollo intermediate.

2. The influence of self-incompatibility on yield is discussed and supported by yield figures of plots and individual trees.

3. The scarcity of self-incompatibility in the cocoa commercially grown in West Africa may help to account for the yields so greatly surpassing those of the West Indies.

4. The effect of age on incompatibility is discussed.

5. From various pollination experiments it is concluded that self-incompatibility is due to the inhibition of growth of the pollen tubes. Compatible pollen tubes may be inhibited also by the influence of incompatible tubes growing on the same stigma.

Acknowledgment.

I wish to express my gratitude to the Acting Director of Agriculture, Gold Coast, for permission to publish this paper.

Aburi, March, 1938.

References.

1. Shephard, C. Y.—Report on the Economics of Peasant Agriculture in the Gold Coast, 1936.
2. Voelcker, O. J.—Self-incompatibility in Cacao. Sixth Annual Report on Cacao Research, 1936. (Trinidad).
3. Posnette, A. F.—Incompatibility and Pollination of Cacao. A.I.C.T.A. thesis, 1937.
4. Pound, F. J.—First Annual Report on Cacao Research, 1931 (Trinidad).
5. Cheesman, E. E.—Fertilization and Embryogeny in Theobroma Cacao. *Ann. Bot.* 41 (1927).
6. Sears, E. R.—Genetics 22. 1. January, 1937.

OBSERVATIONS ON BEHAVIOUR OF CITRUS ROOT-STOCKS IN ST. LUCIA, DOMINICA AND MONTSERRAT.

By R. G. Fennah.
(*Advisory Department, Imperial College of Tropical Agriculture.*)

Introduction.

The following notes have been accumulated during visits paid by the writer to Government citrus nurseries and demonstration plots, estates and peasant cultivations during the past three years in the islands of St. Lucia, Dominica, and Montserrat. As will be seen, no attempt is made to reach a final judgment on the question of the most suitable stock for general use with citrus in these islands: at present the data show clearly the need for prolonged observation before any permanent ranking on the basis of general merit can be attempted.

Budding of citrus on different root-stocks was advocated in Dominica at least as far back as 1908 partly, it is believed, on account of the superior yield recorded from certain budded types, and partly in the expectation that by this means seedling limes would be provided with a more deeply-penetrating root system. With the exception of experimental work, and of distributions made on a small scale by the Department of Agriculture, little was done until after 1928, when the extensive dying out of old seedling cultivations and the destruction caused by the hurricane of that year forced a general change of planting policy. There existed at that time only a scanty experience of the performance of budded trees under estate conditions, and certainly few valid reasons for preferring one stock to another. Experimentation was begun by the Agricultural Department and by planters interested in this phase of cultivation. The first dissemination of material on a large scale was confined to citrus budded on sour orange, and it is concerning this stock that opinion to-day can most reliably be formed.

In St. Lucia a similar dying of the major fields of seedling limes in the years around 1934 caused budded trees to become standard planting material. Sour orange stock was used in the nurseries of the Agricultural Department, and since then has been employed consistently for plantation work. Devastation of the seedling cultivations on the light-soil areas in Montserrat between 1934 and 1937 also led to the adoption of budded plants for these soils. Owing to the great contrast in environmental conditions with the more humid islands farther south the Department of Agriculture has undertaken exploratory work in this problem by means of an experiment in which rough lemon, sour orange, and Seville sweet orange, used as stocks, are being compared with one another and with West Indian lime on its own roots. Field propagation of budded limes has been started by a company with interests in the island, and, in this work, sour orange has been used exclusively.

The Behaviour of Certain Stocks.

(1) Seedling Lime.

Before passing to a consideration of stocks proper it is worth noting the characteristics of the root system of the West Indian seedling lime. This, in very light soils, such as that found near Plymouth, Montserrat, develops downward and outward, forming a very desirable shape. In heavy soils, or on thin soils overlying rock or stiff subsoil, extensive and straggling surface roots are produced. Although the cambial tissues are generally regarded as being by no means immune to "Collar-rot", the writer, in examining several hundreds of such seedlings, sometimes growing in swamp conditions, has noted merely a few examples of "Collar-rot", and some of these were doubtful. Compared with other citrus this performance by trees growing under humid conditions for much of the year, and often in the roughest state of cultivation, must be considered as distinctly good. Moreover, the tolerance of seedling limes of attack at the roots by the larvae of citrus weevils (*Diaprepes* spp.), is fairly high. The most serious disadvantage attending the use of seedling trees is that under certain adverse conditions (such as low dry-season humidity, low soil moisture, or, conversely, waterlogging, and exposure to heavy attack by Withertip disease) portions of the root system fail, on account of the dying of the outermost fine rootlets, and ultimately from a cluster of dead rootlets a dead strip is formed along the major root which it joins, and extends up the trunk, finally embracing the whole of a limb, which sheds its leaves and dies. This death of sections of the tree cannot be arrested completely, as far as is known at present, but can be delayed for an indefinite period by watering in the dry season and by the provision of overhead shade, when the affected trees are growing in moderately heavy soil. In very light soils trees usually succumb completely, instead of progressively by sections, though the order of dying of tissues (from root upwards) is identical with that already given. It is this susceptibility to almost irreparable injury during unfavourable climatic periods (a susceptibility which has appeared in an intensified degree in the last twelve years) which has brought seedling cultivation into disfavour in all but a few localities, or has prevented attempts at renewal. This unfortunate development makes any general statement on the longevity of seedling cultivations in the Lesser Antilles practically meaningless. Yet, in Montserrat, in two localities trees may still be seen which have occupied the same spot for over forty years, periodically regenerating themselves by the sprouting of "dormant buds" from near the roots.

(2) Sour Orange.

Sour orange stock, at present that in most general use, has given satisfactory results to date on the leeward side of Dominica, in the Soufriere valley in the south-western part of St. Lucia, and at Union Experimental Station and several estates in the north. In these areas gummosis is uncommon on such stock, and if present makes headway very slowly.

It was formerly believed that limes budded on this stock would be more securely held in the soil—a point of some consequence in the hurricane zone. This idea was probably founded on the observations (i) that seedling limes do not produce deep roots under field conditions in St. Lucia and Dominica and (ii) that in the nursery bed sour orange usually develops a large tap root, sometimes as long as the above-ground stem. It has been established however, that this tap-root does not persist after transplantation of the tree, but dies back to the crown, either immediately or after a few years of growth (1). In the Lesser Antilles two factors which cause this death of the tap-root are damage in the process of transplanting and attack by larvae of Citrus Weevils: it is likely that there are others. Whether or not other vertical roots develop in its stead appears to depend largely on location; in general the root system of the sour orange under field conditions in the Lesser Antilles is similar to that of seedling limes on the same soil, with the possible difference that the number of large roots near the crown is less. The yields of fruit from trees budded on sour orange are higher than from seedling limes grown under the same conditions and of equal age, providing that severe attack by insects does not occur (*see* Tables 1 and 2). Moreover, a budded tree usually comes into bearing between two and a half years and three and a half years, as contrasted with the four years, or more usually five, taken by a seedling lime. Where trees are budded low (2 ins. to 3 ins. above ground level) the resulting tree, if a lime, has the low-branching straggling habit of the seedling. If budding is carried out above 18 ins., the tree develops a hemispherical canopy which is fairly neat, if sometimes high. Attempts to train scions into a more pendent shape have been made with some success, but with limes caution is necessary owing to the readiness with which the branches split longitudinally at the forks.

Table I.

Comparison of yields of budded and seedling limes in 1922-23 at the Botanic Gardens, Roseau, Dominica, expressed as barrels per acre.

No. of ¼-acre plots.	Date when planted.	Yield.	Type of plant used.
5	1913	340	Seedling lime.
2	1914	506	Lime budded on sour orange.

N.B.—These figures were extracted by H. B. Pidduck, Esq., Assistant Agricultural Superintendent, from the Report of the Agricultural Department for 1923. They have been chosen with a view to lessening probable error due to locality, since in the original trials no randomised system of planting was adopted.

Table II.

Comparison of yields of budded and seedling limes over the period 1921-22 to 1927-28 at the Botanic Gardens, Roseau, expressed in barrels.

No. of ¼-acre plots.	Seven years' yield.	Average yield per acre per annum.	Type of plant used.
1	690	251	Lime budded on sour orange.
1	654	239	do.
1	446	162	Seedling lime.

The first plot in the table was given a green dressing of *Tephrosia* for the first three years after planting. The second and third plots were merely weeded for the same period. When manure was applied, a complete dressing was given to all plots. In comparing the yield per acre with that of Table 1 it must be remembered that the latter covers only the period during which Wither-tip disease has been present.

The tolerance of this root stock for insect attack is not particularly high. The feeding tracks made by weevil larvae on a healthy root are readily callussed and no important secondary infestation by other insects or by fungus has been found to take place at points of injury. The relatively few main roots which are produced, however, are commonly so disposed that the random feeding tracks of a few weevil larvae below the crown may girdle them in a few months, with the result that the tree falls into an unthrifty condition from which it cannot readily recover. At one estate seedling limes were interplanted with limes budded on sour orange, and within a few years the whole cultivation was subjected to a prolonged series of attacks by weevil larvae. It was found that the disparity in tolerance of attack was so great that the seedling limes could be picked out from the yellowed or defoliated budded trees at a distance of many yards.

The principal objection to this stock, however, lies in the great variation in its growth and thriftiness on different soils. In the localities where it is now most extensively used the stock, in general, remains conformable in girth to the scion: in other localities, either drier, or of a certain soil type, the scion outgrows the stock and overlaps it markedly after a few years (*see* fig. 1). This may be accompanied by several undesirable phenomena, all of which seem ascribable to an insufficient supply of water to the scion at times of low atmospheric humidity. They are as follows:—

(*a*) *Drying Out of Young Fruit.*—The symptoms of this are the hardening and yellowing of young fruit when about ½ in. or ¾ in. long; when the fruit and attached

FIG. 1.—*Uneven growth of lime scion on sour orange stock.*

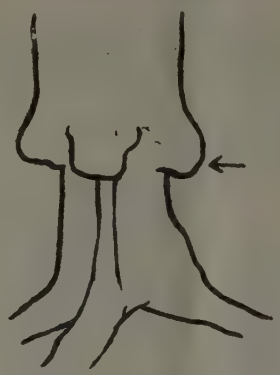

FIG. 2.—*Uneven growth of lime on rough lemon stock.*

FIG. 3.—*Uneven growth of lime scion on wild grapefruit stock.*

The bud union is indicated by an arrow. Figs. 2 and 3 were drawn from low-budded specimens in the field.

stalk are cut longitudinally thin brown lines may be observed, indicating gum in the vessels (tracheae) of the wood. Unlike fruit attacked by Wither-tip disease, which fall at the slightest touch, the yellowed and dried fruit are firmly attached to the stalk. It has been found that constant and liberal watering at the onset of dry weather will alleviate this trouble.

(*b*) *Curling of Foliage and Leaf-shed in Dry Weather.*—This has so far been observed only in valleys on the leeward side of Dominica and in parts of the Choiseul area of St. Lucia. Each leaf hangs vertically, coiled parallel to the midrib into a circle. This condition also is lessened by watering: an attempt has been made to reduce it by the provision of overhead shade, but with inconclusive results.

(*c*) *Dieback of the Scion.*—This has been observed in the north-eastern part of Dominica and in the uplands of southern St. Lucia. Its occurrence in these parts gains in interest by the fact that it is here that weevil incidence is at its lightest. The symptoms are firstly, cessation of growth (often no appreciable growth above ground is made from the moment of planting out), and secondly dulling, discoloration, and shedding of the leaves, followed by die-back of the scion to the bud union. In the wet season shoots may sprout from the stock. The above-ground appearance of such failing plants at first strongly suggests that severe damage has been sustained by the roots, but these, when exposed, are often found to be extensive, and well supplied with healthy rootlets. Examples fitting this description have frequently been examined, and were at one time so common in north-eastern Dominica as to give rise to a general opinion seemingly well founded, that sour orange is of no value as a stock in conditions found there. In Dominica the principal features of areas to which lime on sour orange stock is unsuited are (i) a "brown soil" in close association with what appears to be typical "red earth", (ii) an annual rainfall of approximately 100 ins., or over, and (in parts) seasonal exposure to wind. In St. Lucia dying of the scion is most common in a region of low rainfall (50 ins. to 70 ins.), on a soil derived under rather dry conditions from compacted ash with boulders, and in spots greatly exposed to wind in the dry season. Dying back of scions has been found to a lesser extent in localities not conforming to the above types. Of the miscellaneous specimens included here certain young trees were found to be growing in a soil of high available nutrient content, and were attacked at the roots by citrus weevils, and exposed both to low humidity and to seasonal wind. In their case the water supply to the scion was probably not rapid enough in very dry weather, since, in spite of root injury the stocks remained alive. In Dominica, however, there can be little question of the ability of the roots to obtain water.

It is possible that in many cases scale insects accelerate the dying back. Purple scale (*Lepidosaphes beckii* Newm.), commonly infests the stems, and White, or Snow scale (*Pinnaspis minor strachani* Cooley*), have been observed repeatedly to affect the scion of lime budded on sour orange, and to cease abruptly at the bud union. This is highly suggestive of a difference in vigour above and below the bud union, as sour orange is

* This is a tentative determination by Dr. H. Morrison, of the Bureau of Entomology, United States Department of Agriculture.

not immune to attacks of Snow scale. The rapid growth of any shoots that may spring from buds beneath the bark of the stock indicate that in itself it is healthy.

A possible explanation for the facts given above is that the junction between the sour orange stock and the scion of lime is not perfectly efficient in some plants, and under stress of rapid transpiration the water content of the scion becomes lowered, and also the supply of nutrients in the cortical tissues may be retarded by malformation at this point.

As regards longevity, no upper limit can yet be quoted for trees budded on sour orange in the Lesser Antilles. In the Government citrus plots at Roseau, Dominica, trees of this type, fully forty years old, are still in satisfactory condition, and bear well.

(3) Rough Lemon.

Rough lemon stock is used on a commercial scale in Dominica, chiefly in the areas in which sour orange stock has proved to be unsuitable. It is also included for observation in the budded material maintained by the Agricultural Departments of St. Lucia and Montserrat.

The number of root systems of rough lemon examined by the writer has been comparatively few, and the impression has been gained that its general root habit is similar to that of sour orange. Its tolerance of weevil attack can at present be fairly estimated only in Montserrat (since elsewhere it is used in parts where weevils are not very abundant), and again a similarity to sour orange is to be noted. It differs markedly from sour orange, however, in that in Dominica it has proved to be susceptible to gummosis, and in the north-eastern area loss of trees from this cause is very common. Examples have been observed in the field which have strongly suggested that the scion of West Indian lime was far more resistant to gummosis than the rough lemon on which it was budded. In the drier conditions of Montserrat the rough lemon stock, has so far remained free from this disease.

Apart from the above weakness, the general field habit of this stock leaves much to be desired, as far as can be judged from a single district. Young lime plants on this stock were established without difficulty in the northern district of Dominica and growth proceeded satisfactorily in the early stages. Later, after trees had matured and were in bearing, the scion, in almost all trees increased in girth more rapidly than the stock, with a resultant overhang (*see* fig. 2). At the same time growth slowed considerably, and some die-back of twigs and branches occurred (possibly induced in part by heavy attacks of Wither-tip disease, but certainly not entirely, as healthy lime trees on another stock were abundant in the same locality). Once they have reached this stage such trees, as far as present observation goes, often "stand still", and make no headway in growth above ground.

The writer has not encountered any old trees on this stock; the oldest trees examined did not exceed ten years.

(4) 'Gospo' or Bitter Orange.

Though large and well-developed trees known to planters under these names are quite common in Dominica and St. Lucia, little use has been made of this variety as a stock for other citrus. The root system, to judge by a few examinations, does not appreciably differ from that of sour orange. On such reputed examples of material budded on this stock as have been examined, growth of scion and stock has been uniform, and the general appearance of the budded trees has been satisfactory. The writer has no information concerning its growth in dry habitats, while in areas where Citrus weevils are moderately abundant, its tolerance of attack is the same as that of sour orange. The chief objection to this variety as a stock appears to be its liability to attack by gummosis. This is more marked than that of rough lemon.

(5) Seville Sweet Orange.

Seville sweet orange is the name given to a local variety used as a stock in Montserrat. In the part of the island in which it is used conditions are dry and the soil is sandy and well drained. Trees over ten years old, budded very low, have been grown in a plot on one estate, and have equalled in growth seedling limes in surrounding fields. This plot formed a striking contrast to the seedling cultivations when they were dying rapidly in 1936, and has survived to the present time. Owing to the low budding initially practised no observations were possible on the relative rates of growth in girth of scion and stock: to judge from the height and lateral development of the trees there is no reason to suspect any retardation of growth at any stage. Tolerance of attack by larval *Diaprepes* is averagely good. The results with this stock under conditions in Montserrat have been sufficiently satisfactory to justify its selection for comparison with rough lemon and sour orange in an experiment with stocks for ultimate commercial use in the island.

No trees affected with gummosis have been noted by the writer in Montserrat; but it would not be surprising if this stock were to develop gummosis if employed in humid localities.

(6) Rangpur Lime.

Rangpur lime is not used commercially as a stock in the Lesser Antilles. In Montserrat the flourishing condition of certain trees at one time suggested the possibility of usefully employing it in this way, but no trials were made, and on evidence from elsewhere there is reason to suppose that results would have been indifferent. Budded citrus embodying Rangpur lime wood which has been seen by the writer has been uniformly unsatisfactory. A few trees budded on this stock were examined in eastern Dominica. They were not bearing fruit, and were extremely stunted for their age: the branches were few and the foliage sparse. Moreover the root system was so

poorly developed that the trees swayed easily when pushed. It may have been that this unthrifty condition was partly due to the soil in which the trees had been planted, though close at hand limes on another stock were growing satisfactorily. Another set of trees examined by the writer in a different area had consisted originally of Rangpur lime budded on sour orange and for market reasons had later been top-worked with a variety of lime-lemon. A representative number of these trees was seen, and, when compared with lime-lemon budded directly on to sour orange, of slightly more recent planting, they were in every case more stunted both in height and spread of canopy. Foliage comparison of the scions on the respective stocks could not be made, as the sections of Rangpur lime wood were so heavily attacked by gummosis that the portions of the tree above were approaching a moribund condition. Efforts to treat the diseased wood by the accepted surgical methods had been nullified by the rapidity with which outbreaks occurred from fresh centres.

(7) Wild Grapefruit.

There appears to be a popular confusion of nomenclature between this tree, the shaddock, and self-sown grapefruit of early commercial varieties. Of the few trees of this variety which have been shown to the writer, all have carried fruit externally identical with cultivated grapefruit, and exhibiting neither the coarseness nor the size of the shaddock. The taste of the fruit was acid and bitter. A characteristic feature appears to be erect growth, sometimes to fifteen or twenty feet, accompanied by compact, and scarcely less erect branching, giving in extreme forms an appearance slightly reminiscent of the inverted head of a native broom. Numerous spines, reaching a length of some two inches project from the trunk and most of the branches.

This plant has gained favour in Dominica within recent years as a stock for limes and for cultivated grapefruit. Although experience has yet to be gained regarding its value over a long period, certain features have already evinced themselves sufficiently to be accepted as characteristic. Firstly, the stock appears always to equal, and usually to be decidedly superior to all stocks previously mentioned in vigour of growth. After a few years the girth of the stock exceeds that of the scion, giving the effect shown in fig. 3. Limes budded on this stock flourish in areas in which sour orange is valueless. On one estate the writer had the privilege of seeing a cultivation in which limes budded on wild grapefruit and on rough lemon were planted alternately, those on wild grapefruit being the younger by one or two years. In height, spread of branches, and in girth of stem they equalled or exceeded their neighbours, and differed also in having little or no dead wood, as contrasted with occasional dead patches among the branches of the limes budded on rough lemon. The fruit of these budded trees had no undesirable qualities, while in experiments carried out by the Department of Agriculture of Dominica limes budded on grapefruit have given higher yields than those on sour orange, in an area where sour orange is considered suitable for propagation. No gummosis of any kind has been seen by the writer in a scrutiny of over a hundred trees: that the degree of resistance is high to one fungus at least, may be inferred from the fact that lemon scions, budded rather low on wild grapefruit, have been found affected with a form of gummosis in the lower branches and on several trees the diseased patch, large enough to be of some months standing was bounded sharply below by the bud union.

In the north-eastern district of Dominica results with this stock over a period of some seven years have been so satisfactory that it is now supplanting rough lemon as the standard commercial stock, and is being distributed by the local Department of Agriculture.

By way of indicating the need for caution in appraising the general value of this stock an instance must be recorded where the writer was shown a mature lime tree, on wild grapefruit stock, which for reasons at present obscure had developed a completely erect habit, with the branches growing almost vertical after leaving the trunk. At a short distance the tree bore a strong resemblance to a mature wild grapefruit. The estate manager who demonstrated this specimen stated that several of his limes on wild grapefuit stock had produced trees of similar habits. So far no examples have been noted elsewhere.

Wild grapefruit is used also as a stock for cultivated grapefruit, and as far as the writer is aware, results have been consistently good. Even with such closely allied varieties there is still a tendency for the stock to outgrow the scion in girth. A cultivation of well-established grapefruit trees on this stock seen near Marigot, in Dominica has for years left nothing to be desired in vigour and size of trees, in yield, and in quality and texture of fruit.

(8) Citron.

In the Lesser Antilles, citron appears to have been tried as a stock for limes only in Dominica, and the results have been summed up as follows: "The experiments made in budding the lime on the M'gergeb stock, a variety of citron obtained from Algeria by way of the Royal Botanic Gardens, Kew, and on the common citron, and their subsequent testing in the field were brought to an end. After four years in the field, with the same attention as that accorded to seedling limes and those budded on sour orange stocks, the plant may be said to have merely existed, and but little growth was made. This line of work has proved that the citron is of no use as a stock for the lime" (2).

References.

1. Fennah, R. G.—A Note on the Development of the Root System of Budded Limes after Transplantation in St. Lucia. *Trop. Agriculture* XIV, No. 7, p. 211.
2. *Rept. Agric. Dept., Dominica* 1919-20, Barbados, 1920.

PREPARATION OF CITRUS FRUIT JUICES.*

CITRUS fruit juices come on to the market in various forms, as (*a*) cordials, (*b*) squashes, (*c*) pure fruit juices, with or without fruit cells, (*d*) juices for special purposes such as concentrates for use in the milk bar trade, &c.

Cordials are clear beverages consisting of fruit juice to which has been added syrup, usually together with small quantities of flavouring and colouring materials. Squashes differ from cordials in that they are cloudy, due to the presence of fruit cells and suspended matter in the juice used in their preparation. The proportion of fruit juice in these beverages varies somewhat according to the particular brand, but it may be regarded usually as forming from about a third to half of the whole. Both cordials and squashes are also prepared in an aerated or carbonated form.

Early in the development of the citrus fruit juice industry all citrus juices were rendered clear, but the trend to-day, with the exception of lime juice, is towards a cloudy or pulpy juice.

During recent years a great deal of work has been done, particularly in the United States, in devising methods of preserving citrus juices in their natural state without the addition of preservatives or other materials. In America large quantities of citrus juices are consumed in this form, but so far as the United Kingdom is concerned cordials and squashes are still the popular type of beverages.

The juices of the different citrus fruits vary in keeping properties and the methods of manufacture vary somewhat accordingly.

Lime juice manufacture, for instance, presents comparatively little difficulty. The whole fruit is crushed between rollers which express the juice together with the essential oil from the peel. The oil is then separated by centrifuging. The juice is allowed to settle and the clear liquid drawn off, preservative in the form of sodium or potassium metabisulphite added and the juice packed in casks.

The extraction of the juice from the other important citrus fruits such as orange, lemon and grapefruit is carried out briefly as follows. In the most commonly used method the whole fruit after washing is cut in half at right angles to the axis of growth and the juice extracted by pressing the halved fruit against a revolving conical ribbed or grooved extractor or burrer. By adjusting the speed of the burrer, it can be so arranged that the inclusion in the juice of any considerable amount of "rag" or pith and essential oil from the peel can be avoided. The large pieces of fruit particles and seeds are then removed by screening, leaving behind only the finer fruit cells. When required for the manufacture of squash, the juice is shipped in this form in casks with the addition of preservative.

According to the Food and Drugs Act, sulphur dioxide and benzoic acid are the only preservatives permitted in non-alcoholic beverages sold in the United Kingdom. The product when retailed to the consumer must not contain more than 350 parts per million of sulphur dioxide or 600 parts per million of benzoic acid. The preservative is usually added in the form of solutions of sodium or potassium bisulphite and sodium benzoate respectively. The equivalent amounts of these three compounds are approximately 570 parts per million of sodium bisulphite, 650 parts per million of potassium bisulphite and 710 parts per million of sodium benzoate.

Benzoic acid often imparts an unpleasant "burning" taste to fruit juices and the use of sulphur dioxide preservatives is generally preferred. Raw fruit juices when imported into the United Kingdom normally contain approximately the following amounts of sulphur dioxide per million:

Lemon and lime juice	350 parts.
Grapefruit juice	650-750 do.
Orange juice	750-850 do.

As the juices are usually diluted two to three times in making up beverages, the content of sulphur dioxide in the final product is well below the permissible amount. Further preservative is then often added to bring the content up to 350 parts per million.

In the case of orange juice a certain amount is prepared in the concentrated form in order to save bulk in shipment. For this purpose the juice is roughly filtered before concentration and concentration is carried out under reduced pressure in special plant.

As already mentioned, the demand in the United Kingdom is for cloudy citrus fruit juices. The removal of suspended matter, though in some cases it improves appearance often detracts considerably from the colour, flavour and nutritive value of the expressed juice. The colour and flavour of orange juice depends to a large extent on the suspended particles which it contains and the removal of these gives a straw-yellow product lacking aroma and flavour. Orange juice is therefore now seldom prepared in the clear form.

The efforts in the United States to market citrus juices in a form closely resembling the natural juice has involved additional stages in their preparation. The modern method of manufacturing citrus juices which is carried out extensively in the United States proceeds along the following general lines. After the juice is screened to eliminate the seeds and coarse pulp, it is subjected to a process of de-aeration, *i.e.* the removal of the occluded air in the juice by means of vacuum treatment. It has been found that the presence of air in the juice markedly affects the flavour

* Abstract of an article in *Bull. of the Imp. Inst.*, Vol. XXXVII, No. 3, pp. 359-364, 1939. Further particulars regarding details of processes and names of firms will be furnished by the Imperial Institute.

after storage, particularly if the juice has to be submitted to heat treatment. De-aeration is accomplished by passing the juice in the form of a fine spray into an evacuated tank. This removes any air which has been occluded in the juice and in the fruit particles. After the tank is partly filled the juice is held under a vacuum of at least 27 in. for about 10 minutes. The vacuum may then be relieved, preferably with an inert gas such as nitrogen.

Immediately after de-aeration the juice is passed to a flash pasteuriser. Usually the de-aerating unit is connected with the pasteurising unit so that the juice does not come in contact with air until it issues hot from the pasteuriser. Flash pasteurisation consists of subjecting the juice to a high temperature, in the neighbourhood of 200°F., for a very short period, sometimes only a few seconds. In ordinary pasteurisation, of course, the juice is heated at a lower temperature for some time. After flash pasteurisation the juice is packed either in cans or bottles under vacuum. Grapefruit juice has better keeping properties than either orange or lemon.

If a clear juice is required the method most generally applicable depends on the fact that by heating the juice the colloidal matter is coagulated and will then settle out readily and can be removed by filtration. The de-aerated juice is passed through a flash pasteuriser and held at about 180°F. for about a minute, cooled rapidly, a quantity of filter aid, such as kieselguhr, added and the whole passed through a filter press. Such a process gives a fairly good product, but as already pointed out it is inferior to the juice in which the fruit cells are allowed to remain. Another method used for preparing clear juices is clarification by the gelatin-tannin process* which is as follows:—

"The bulk of the suspended matter, particularly in apple juice, consists of protein and pectin-like substances. These colloidal substances carry an electrical charge, generally negative, and are precipitated when this charge is reduced to zero by the addition of a colloid bearing an electric charge opposite in sign to that of the colloid to be removed. Gelatin and casein act in part in this manner and in part by forming insoluble precipitates with the constituents of the juice (casein with acid, gelatin with tannin) which on settling carry with them other suspended particles.

"The gelatin-tannin process is the most widely used colloid-precipitation process for clearing fruit juices, but since the chemical reaction involved must be accurately adjusted for each juice and each type of gelatin used, considerable time and experience are necessary in making the required tests. Laboratory tests are first conducted to determine the correct amount of gelatin to add for the juice to be treated. Since there is danger of clouding the juice by the use of too much gelatin, tannin is usually added so that no excess of gelatin remains. The addition of tannin to the juice also helps to minimise the bleaching of the colour that occurs during a gelatin-tannin clarification, since the added tannin helps to replace the natural tannins of the juice removed during clarification. In commercial practice about 1.25 oz. of tannin and from 1.5 to 6.0 oz. of gelatin, according to the condition of the juice, are required per 100 galls. The tannin is added first to the juice, the juice being well stirred next the gelatin solution, the juice being agitated during and for several minutes after the addition of the gelatin solution. After this the treated juice is allowed to stand undisturbed for 18 to 24 hours for the precipitated matter to clot together and settle out. The clarified juice is then siphoned off the sediment, care being taken not to disturb the latter".

Another widely used process of clarification, particularly for apple juice, is by the use of pectin-destroying enzymes. These transform pectin into insoluble pectic acid which on precipitation carries down other suspended matter. There are various enzyme preparations on the market, and the manufacturer's directions should be closely followed if the best results are to be obtained. The amount to be used will depend on the type and activity of the enzyme, the amount of suspended matter in the juice, the composition particularly the acidity, of the juice and the temperature and time of storage. After clarification by enzymes the juice must be heated to 150°F. to prevent any further enzyme action.

As citrus juices contain considerably less colloidal and pectinous material than apple or grape juice for instance, methods of clarification such as those mentioned above are sometimes omitted, and the clear juice prepared simply by centrifuging to remove the bulk of solid material, and then filtered through pulp filter after the addition of a filter aid.

In the older methods the extracted juice was allowed to defecate, *i.e.* it was allowed to stand until the solid matter settled out in a layer at the bottom of the container. Preservative such as potassium metabisulphite was added to prevent fermentation during the process. After the juice had defecated a sufficeint length of time it was passed through a pulp filter, filter aids being sometimes used. The clear juice was then pasteurised in bottles or casks. Although with citrus juices prepared by this method there is very little settling out on storage, the quality and appearance bears no comparison with juices prepared by up-to-date methods.

The type of juice to be manufactured will depend entirely on the market to be supplied. If a fastidious taste is to be met and one which demands a juice closely approximating to the fresh, natural product then every precaution must be introduced into the method, resulting in higher costs of plant and manufacture. If, however, a fruit juice cordial, making no pretence at approaching the nature of the fresh juice, is required then extraction, followed by filtering and addition of syrup, flavouring and colouring materials, and preservatives will probably suffice,

* Circular 344, Agric. Expt. Station, California.

REVIEWS.

IMPERIAL ECONOMIC COMMITTEE.*

Among the useful activities which the outbreak of war has checked, is the work of the Imperial Economic Committee. According to the addendum to the Committee's report of 1938-39, the Committee when war broke out was issuing each week, detailed information on the production and trade in Fruit and Dairy Products, each month similar information on Wool and on Canned and Dried Fruit, and each quarter on Tobacco. In each case these were followed by an annual review bringing together the main facts of the year. Also each year it published summaries of world production and international trade in groups of allied commodities with special reference to the share therein of the countries of the British Commonwealth. These under the titles of Grain Crops, Meat, Fruit, Dairy Produce, Vegetable Oils and Oilseeds, Industrial Fibres and Plantation Crops, covered 61 commodities, which with the exception of minerals, include all the important food and raw materials which form the basis of international trade. In addition it supplied the B.B.C for use in its Empire service with twelve summaries—nine of them weekly—of economic information of special interest to the various parts of the Commonwealth. This regular but varied work was in addition to the Committee's other duties of reporting to the Governments of the Empire on economic questions referred to it by them. Up to the outbreak of war it had made 32 such reports, besides surveys of World Production and Trade in several commodities.

The Reports and Intelligence Services of the Committee are well known and widely quoted. They are prepared primarily for official use and the free issue to government departments in all countries of the Empire, to the Press and to research institutes, is large. They are also on sale. The receipts from subscriptions and sales afford evidence of their utility and of the cheapness of the whole service. The total expenditure of the Committee in 1938-39 was £24,042 against which sales of publications realised £4,383—a high proportion for this type of work, especially bearing in mind the size of the free issues.

As the Committee has repeatedly said, its work is only possible through the aid of many engaged in the various trades and of correspondents in several foreign countries. It is clearly impossible to publish in war time information of the type which the Committee compiled, and with effect from 2nd September, 1940 it suspends all its activities. With the exception of a small nucleus all its staff has been temporarily transferred to the Armed Forces or to the Ministries of Supply and Food.

The Committee is a truly inter-imperial organisation, financed in agreed proportions by the Governments of the Empire, and composed of their representatives. Through its members it is responsible to all those governments and not to any one. Though its work is interrupted, the Committee as such remains in being ready to resume its work when conditions permit. The Chairman is Mr. F. J. de Toit, Secretary to the High Commissioner for the Union of South Africa.

* Imperial Economic Committee: Annual Report, covering the period 1st April, 1938 to 31st March, 1939, published for the Committee by H.M. Stationery Office. Price 6*d*. net. 7*d*. post free.

* * *

ANIMAL BREEDING IN THE LIGHT OF GENETICS.*

This is a record of the major features presented and raised in the discussions on animal breeding in the light of genetics which took place at the Seventh International Genetical Congress held in Edinburgh in August, 1939. Although all the papers published in this account are abstracts they should provide some very useful information for workers interested in the progress of various aspects of animal breeding research throughout the world. The abstracts have been grouped under the following main heads: livestock improvement, statistical considerations, miscellany, artificial insemination, milk yield, selection and performance, and poultry.

* Issued by the Imperial Bureau of Animal Breeding and Genetics, pp. 78, price 3*s*.

MISCELLANEOUS NOTES.

Vegetative Propagation of Cabbages.

With reference to a note on this subject published on page 55 of the March issue of this Journal one reader draws our attention to the following paragraph which appears on page 37 of "Gardening in the Tropics" by R. O. Williams. "In the wet season a very inferior cabbage can be grown, but this is useful when the better ones are not obtainable. It is locally known as the creole cabbage, and is a variety which has been propagated by shoots for a number of years. They never form hard heads, but the young succulent shoots make a good table vegetable. Young plants are raised from shoots taken from old stumps left in the ground from the previous wet season, and treated in the same way as seedlings". This form of propagation of cabbages has been practised for a considerable time in Trinidad.

* * *

Trials with Soybean in Ceylon.*

The results of preliminary investigations into the technique of soybean cultivation in Ceylon suggest:—

(1) That the beans should be drilled at distances which will vary with the size of seed sown.

(2) That the inoculation of seed prior to sowing is beneficial but not essential.

(3) That where inoculation is impracticable, a smaller increase in yield may be obtained by manuring with nitrate of soda.

(4) That lime is beneficial.

* Summary of an article by J. C. Haigh. Reprinted from *Tropical Agriculturist*, Vol. XCIII, No. 3. pp. 150-151, 1939.

CHEMICAL NOTES.

(Compiled by the College Department of Chemistry and Soil Science.)

Trace Elements in Fertilizers.

A method has been developed for the simultaneous spectroscopic determination of boron, manganese, and copper in mixed fertilizers. In the samples analysed these elements were present in amounts below 0.1 per cent.

Standards have been prepared that have the average composition of mixed fertilizers, but which have different known amounts of the minor elements ranging from 0.0004 per cent. to 0.4 per cent. An internal reference element, in this case beryllium, was used in this work. It is present in the standards and is introduced into the samples to be analysed in the constant amount 0.05 per cent. The average deviation of spectroscopic determinations made on these standards was about 16 per cent., which indicates the present accuracy of the analyses for those trace elements in mixed fertilizers.

Boron was present in the fertilizers analysed to the extent of 0.004 per cent. to 0.04 per cent. copper 0.001 per cent. to 0.017 per cent.; and manganese, 0.005 per cent. to 0.11 per cent. The desirability of the use of an internal reference element, as in the present instance the element beryllium, and the importance in the direct current are excitation of the complete burning of the sample will be discussed.—(*Chemistry & Industry*, Vol. 58, No. 39, p. 886, 1939.)

* * *

Natural Decomposition of Bat Manure.*

The composition of so-called fresh bat manure varies very considerably, particularly with regard to the phosphorus-content, owing to contamination by lower and more decomposed layers. The phosphoric oxide content of fresh bat manure as collected from caves is usually higher than the original content, since the manure has a very low apparent sp.gr. so that even slight contamination from lower layers richer in P_2O_5 will increase the percentage considerably, but will not decrease the nitrogen-content proportionately. A sample of fairly fresh manure was divided into two parts and from one, unbroken droppings were sorted out (*a*), and the rest was discarded, while the other half (*b*), was roughly screened to separate most of the stones. After grinding and sieving analysis showed (on the dry samples) total nitrogen (*a*) 10.20, (*b*) 8.12; total P_2O_5 (*a*) 4.15, (*b*) 7.15. The moisture-content of fresh bat manure in the air-dry condition is 7 to 8 per cent., and in caves under dry conditions about 11 to 14 per cent. The fresh manure contains about 10 per cent. of nitrogen on the moisture-free material, and 1 to 2 per cent. of P_2O_5, but accumulation, mostly as tricalcium phosphate, may bring the phosphate figure in time up to 40 per cent., although the percentage availability of P_2O_5 (2 per cent. citric solution) is higher in fresh samples. As ammonia is one of the first products of decomposition, and is followed by formation of nitrate, the older, more decomposed manure contains a large proportion of nitrate nitrogen. Nitrogen is lost either through drainage, as free ammonia or as free nitrogen, and the manure contains a very active microflora, causing rapid decomposition of organic matter. Decomposition may be so complete that even the less easily soluble ultimate mineral products, such as tricalcium phosphate, are removed, leaving a residue of silica, iron oxide and alumina, contaminated by sand and dust from the cave. The fresh manure contains enough organic matter with reducing properties to reduce all nitrates present to ammonia when digested with sulphuric acid for the determination of nitrogen by the Kjeldahl process. In old manure preliminary reduction of nitrate is necessary. Leaching accounts for the low proportion of sodium and potassium, the K_2O rarely exceeding 1 or 2 per cent. The original sulphur and calcium contents are about 1 and 0.25 per cent. respectively, but gypsum accumulates rapidly owing to external contamination with calcium.

* Article by J. Vorster Nel. *Sci. Bull.* 155, *Dept. Agr. & Forestry*, S. Africa. Reprinted from *Analyst*, Vol. LXIV, No. 760, pp. 532-3, 1939.

* * *

Boron in Soils.

The fact that there is a very narrow margin between the relatively minute quantities of boron that are necessary for plant growth and the quantities that are toxic makes the accurate determination of boron in soils and plants a problem of major importance.

Two methods of soil analysis for boron are described. Digestion with strong phosphoric acid and separation of the methyl borate by distillation are comparatively easily carried out and seem to represent the maximum available boron in soils. Fusion of the soil with acid sodium phosphate and separation of the boron as methyl borate appears to give the total boron.

The analysis of 93 soil samples representing 27 soil profiles of various members of the great soil groups shows that the Desert, Chernozem and Prairie soils are usually high in boron and that the soils of the coastal plains and the Podzol soils are low. Further work may show a modification of this generalization, due to uneven distribution of boron in the parent geological formations. Soil vary greatly in the differences between the total and the acid-soluble boron. There is considerable evidence to show that this difference represents primary minerals, tourmaline in particular, in the parent rock, although the evidence presented does not exclude the formation of acid-insoluble secondary compounds.—(Abstract of Paper in *Chemistry & Industry*, Vol. 58, No. 39, pp. 886-887, 1939.)